基于IEC 60268-21 标准
声音系统设备的声学测试

Acoustical Measurement of Sound System Equipment according IEC 60268-21

KLIPPEL LIVE

a series of webinars presented by

Wolfgang Klippel

网络研讨会的目标Targets of the Webinar

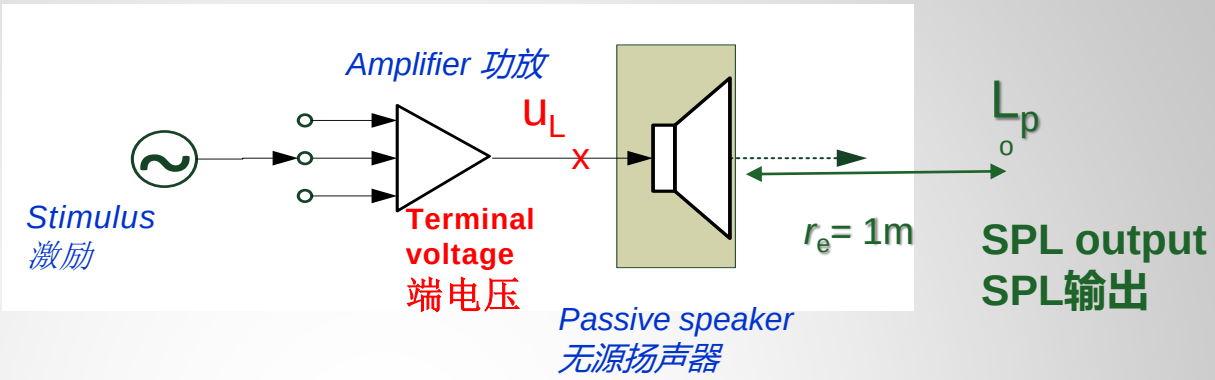
- 在实践中应用新的IEC 60268-21标准（例如测试有源扬声器）
  Apply the new IEC standard 60268-21 in practice (e.g. testing an active speaker)
- 通过生成模拟的自由场条件在普通房间中执行声学测量 Perform the acoustical measurement in normal rooms by generating simulated free field conditions
- 加快方向性测量并研究扬声器与房间之间的相互作用 Speed up directivity measurement and investigate speaker-room interaction
- 全面测试由人工测试激励信号和常见音频信号产生的信号失真
  Comprehensively test the signal distortion generated by artificial test stimuli and common audio signals
- 解读测量结果、避免陷阱、其他技巧 Interpret measurement results, avoid pitfalls, other tips
- 将音频系统的物理和感知评估结合起来 Linking the physical and perceptual evaluation of audio systems
- 讨论开放性问题 Discuss open question

第一节 1st Section
（基于输出的）声学测量
ACOUSTICAL (OUTPUT BASED) MEASUREMENTS

今日议程 Agenda today

1. 现代设备测试中的问题 Problems in testing of modern devices
2. IEC 60268-21标准提供的解决方案 Solutions provided by IEC Standard 60268-21
3. 标准测量条件 Standard measurement condition
4. 针对特定应用的自由和灵活性 Freedom, flexibility for the particular application
5. 实际工作的后果 Consequences for the practical work
6. 问题、讨论 Questions, Discussion

Testing of Passive Loudspeaker Systems
测试无源扬声器系统



定义放大后激励信号的终端电压u_L（对应于标称输入功率P_N）是测试换能器和无源扬声器系统的简便方法（请参阅IEC 60268-5）。

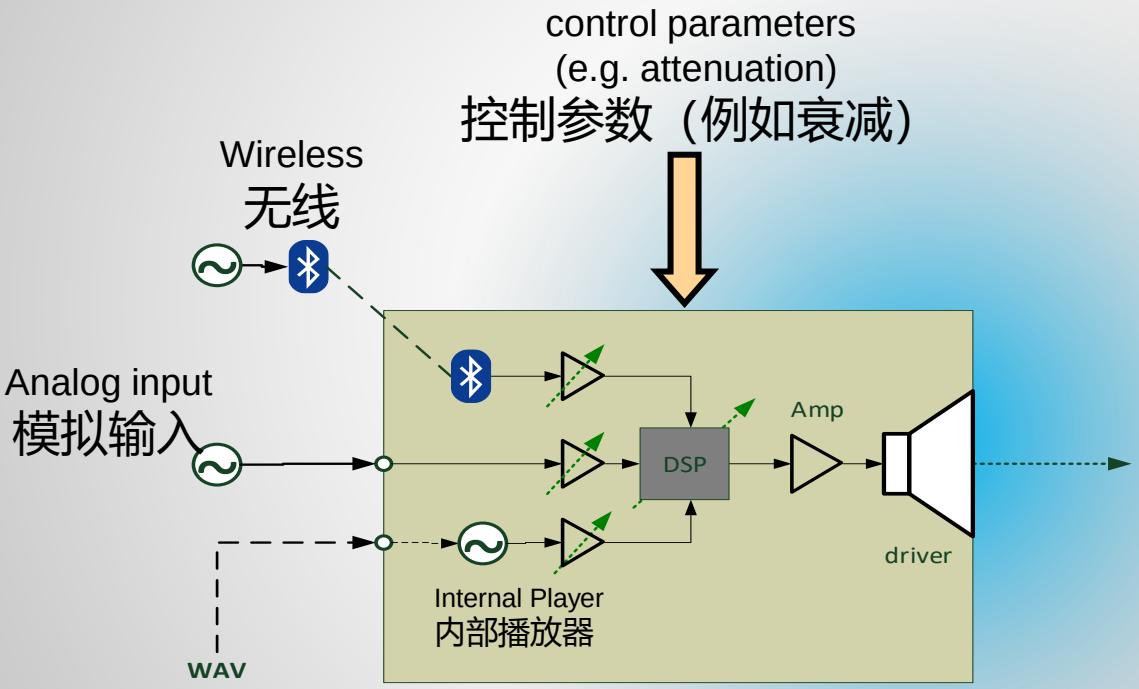
Defining the terminal voltage u_L (corresponding to an nominal input power P_N) of the amplified stimulus was the simple and convenient basis for testing transducers and passive loudspeaker systems (see IEC 60268-5).

For example, the sensitivity of a passive loudspeaker can be expressed as

例如，无源扬声器的灵敏度可以表示为

L_p = 70 dB @ 1m, 2.8 V (1 W)

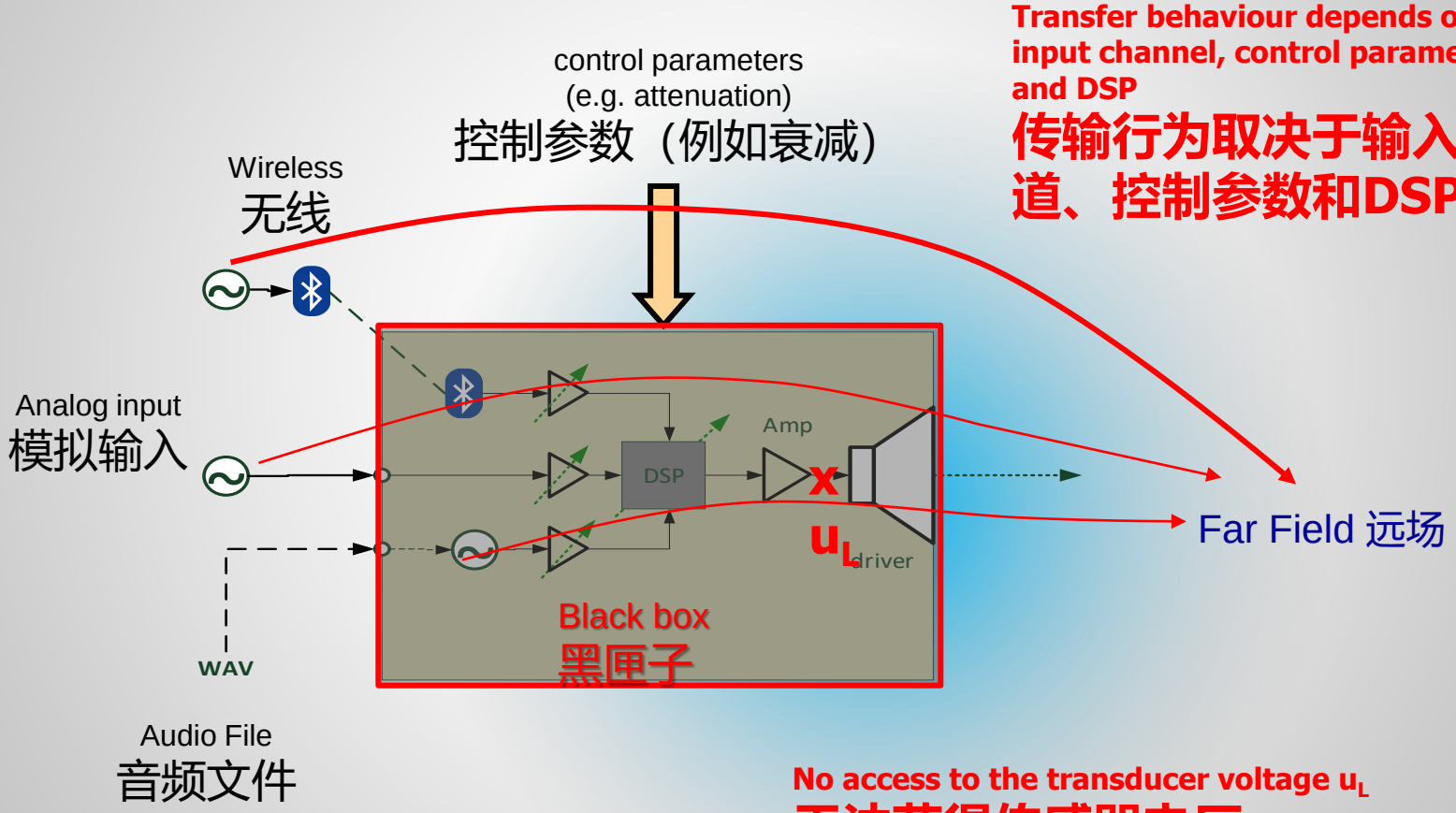
Modern Audio Device
现代音频设备



Far Field 远场

Audio File
音频文件

Consequences for Testing
测试的结果



Transfer behaviour depends on the input channel, control parameters and DSP

传输行为取决于输入通道、控制参数和DSP

No access to the transducer voltage u_L

无法获得传感器电压u_L

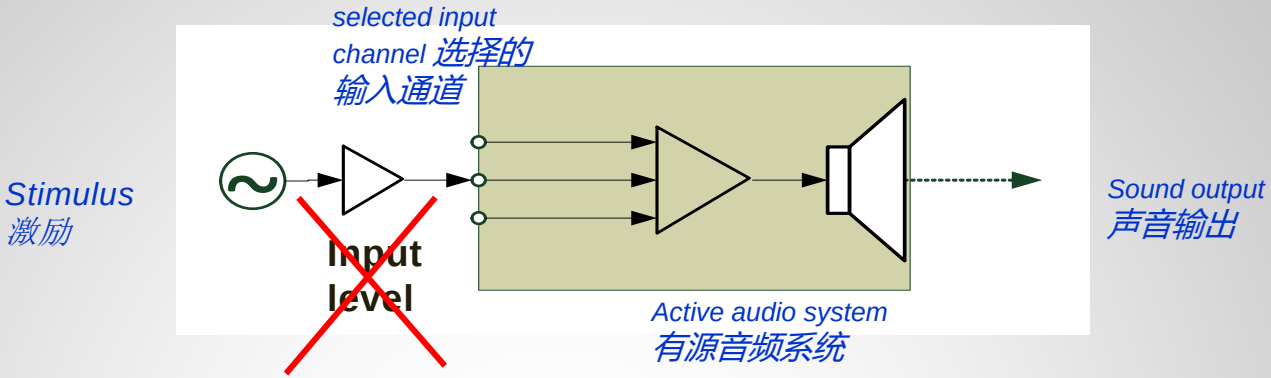
Poll:

投票:

Do you measure the sensitivity of active audio systems?
您是否测量有源音频系统的灵敏度?

- No 否
- Yes 是

Problems for Testing Active Audio Systems
测试有源音频系统的问题



Input level, voltage, electrical input power become less useful for defining the test condition!

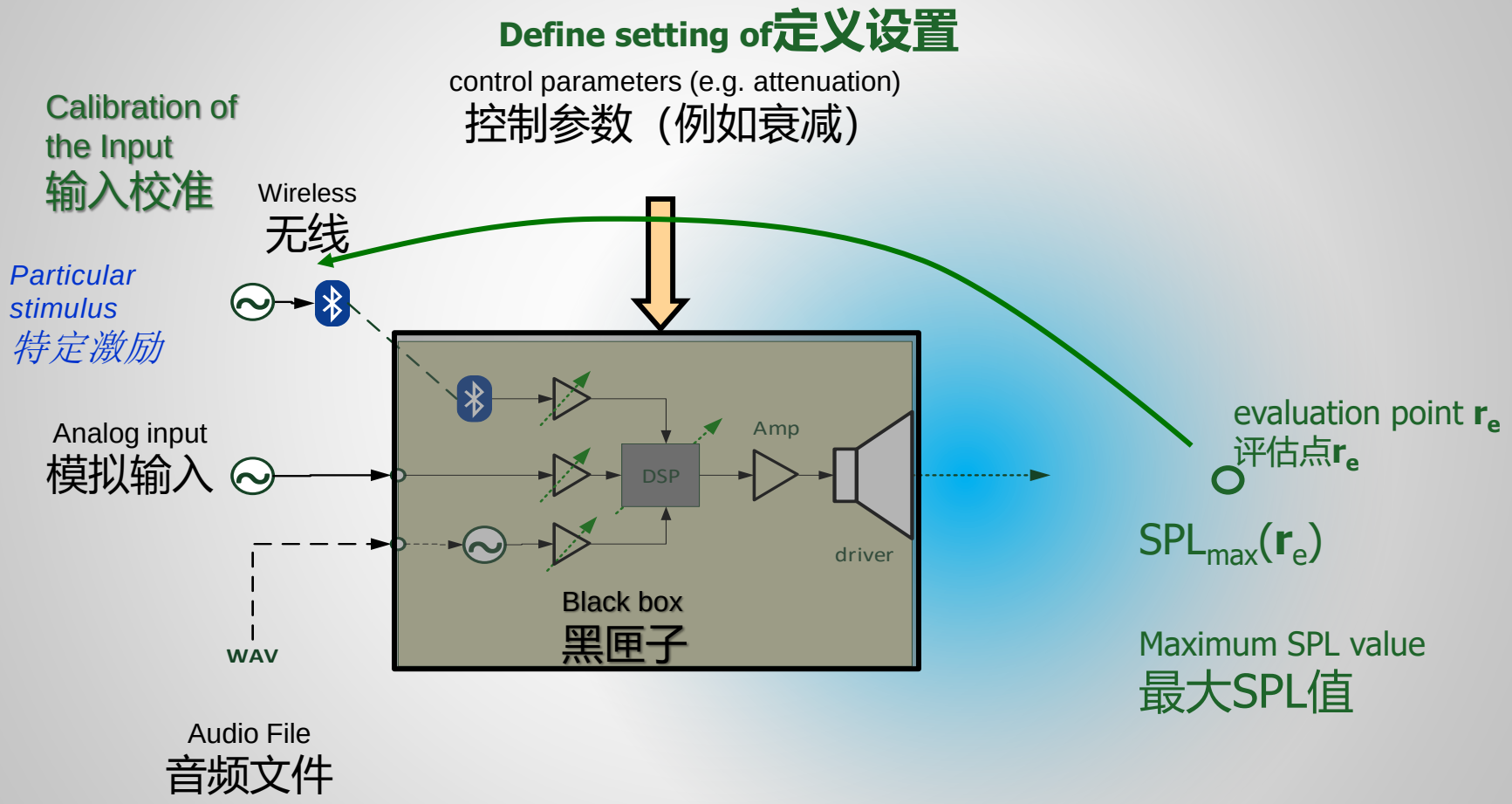
输入电平、电压、输入电功率在定义测试条件时变得不再有用!

Issues of how to:需要解决:

- specify the amplitude of the stimulus?
  如何指定激励的幅度?
- benchmark different devices having different input channels?
  如何对使用不同输入通道的不同设备进行基准测试?
- ensure repeatability and reproducibility of those test?
  如何确保那些测试的可重复性和可再现性?
- avoid an overload of the device under test?
  如何避免被测设备过载?
- define small signal measurements?
  如何定义小信号测量?
- find a simple and practical solution?
  如何找到简单实用的解决方案?

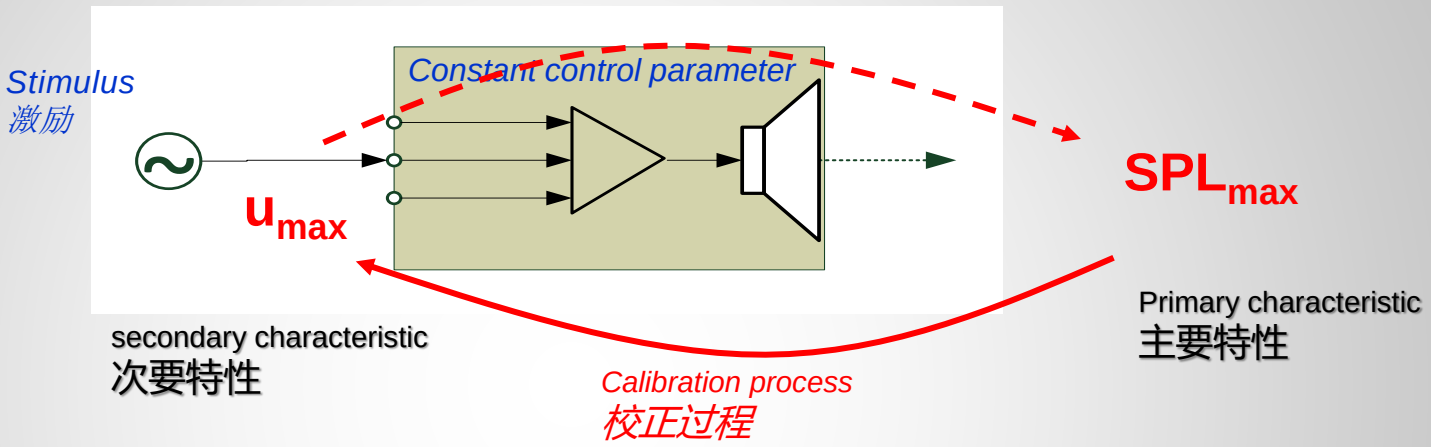
Solution provided by IEC 60268-21

IEC 60268-21提供的解决方案



Maximum Input and Output Value

最大输入和输出值



Rated maximum input voltage u_{max}

额定最大输入电压u_{max}

- Good for (passive) systems with a single input and constant transfer function between input and output
  适用于具有单个输入且输入和输出之间具有恒定传递函数的（无源）系统
- Depends on the input channel
  取决于输入通道
- Depends on the control parameter
  取决于控制参数

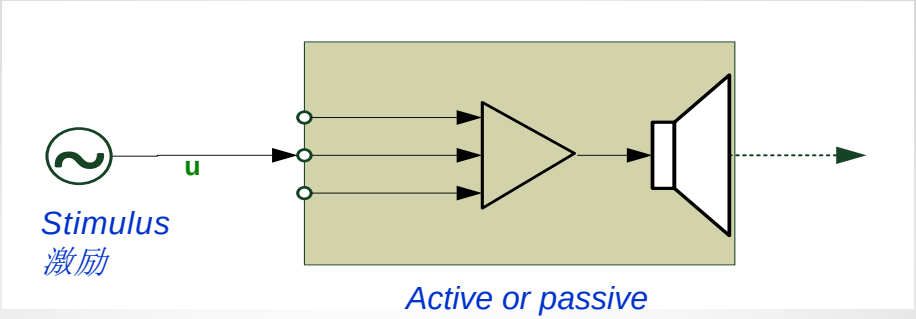
Rated maximum (output) SPL_{max}

额定最大（输出） SPL_{max}

- Universal approach for passive and active systems
  无源和有源系统的通用方法
- Can be applied to any input channel
  可应用于任何输入通道
- Can cope with gain controllers, equalizers, limiters, protection systems, ect.
  可以应对增益控制器、均衡器、限制器、保护系统等。

Who determines the maximum SPL value ?

谁确定最大SPL值?



$SPL_{max}(r_e)$

Definition by IEC 60268-21 由IEC 60268-21定义

- Manufacturer rates the measurement condition (e.g. stimulus, position, environment)
  制造商评定测量条件（例如激励、位置、环境）
- Manufacturer rates SPL_{max} based on information from design, practical measurements and the target application
  制造商根据设计、实际测量和目标应用中的信息评定SPL_{max}

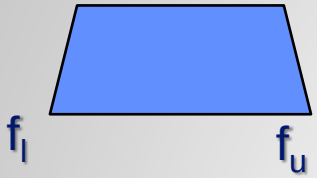
Requirement 要求

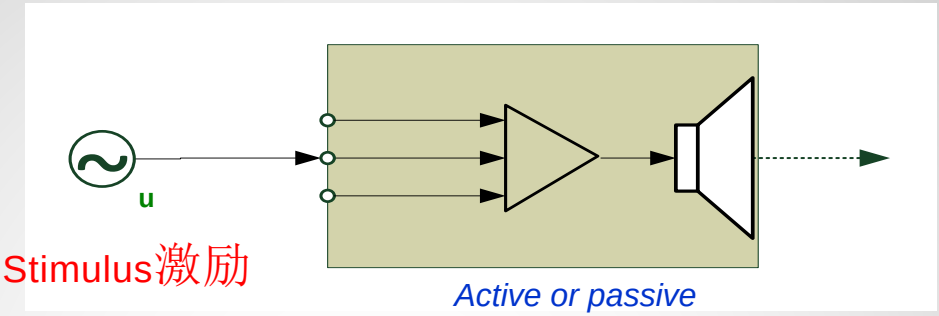
- DUT can reproduce a defined test stimulus at rated maximum SPL
  DUT可以在额定最大SPL下重现定义的测试激励
- DUT will **not be damaged** by the test stimulus during 100h power test
  100h功率测试期间，测试激励**不会损坏**DUT

Benefit 好处

- Maximum SPL value is meaningful for engineering, marketing, final user
  最大的SPL值对工程、市场营销、最终用户都有意义

额定条件：测试激励





$SPL_{max}(r_e)$

Stimulus Properties (IEC 60268-21) stated by the manufacturer:
制造商规定的激励特性（IEC 60268-21）：

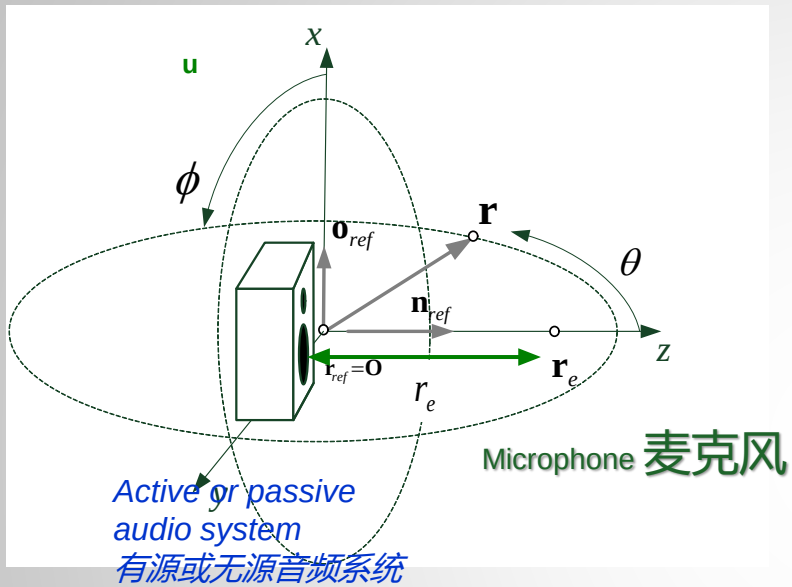
- Broadband (pink or white noise, dense or sparse multi-tone complex)
  宽带（粉红或白噪声、密集或稀疏的多音复合信号)
- Lower and upper limits fl and fu of the rated frequency band
  额定频段的上下限fl和f_u
- Shaping of the power spectrum (e.g. typical program material IEC 60268-1)
  功率谱的整形（例如典型程序材料IEC 60268-1)
- Crest factor (Kurtosis)
  波峰因数（峰度)

Benefit 好处

- The test stimulus represents the typical program material in the final application
  测试激励代表了最终应用中的典型程序材料

Evaluation Point r_e

评估点r_e



Manufacturer states the geometrical conditions (IEC 60268-21)

制造商规定了几何条件（IEC 60268-21)

Position of the audio system (DUT)

音频系统（DUT）的位置

- Reference point rref (e.g. cone center)
  参考点$\mathbf{r}_{ref}$（例如音盆中心)
- Reference axis (e.g. perpendicular to cone surface)
  参考轴（例如垂直于音盆表面)
- Orientation vector oref (e.g. upright position)
  方向向量$\mathbf{o}_{ref}$（例如直立位置)

For example: 1 m distance on-axis

例如轴上1m距离

Position of the microphone

麦克风的位置

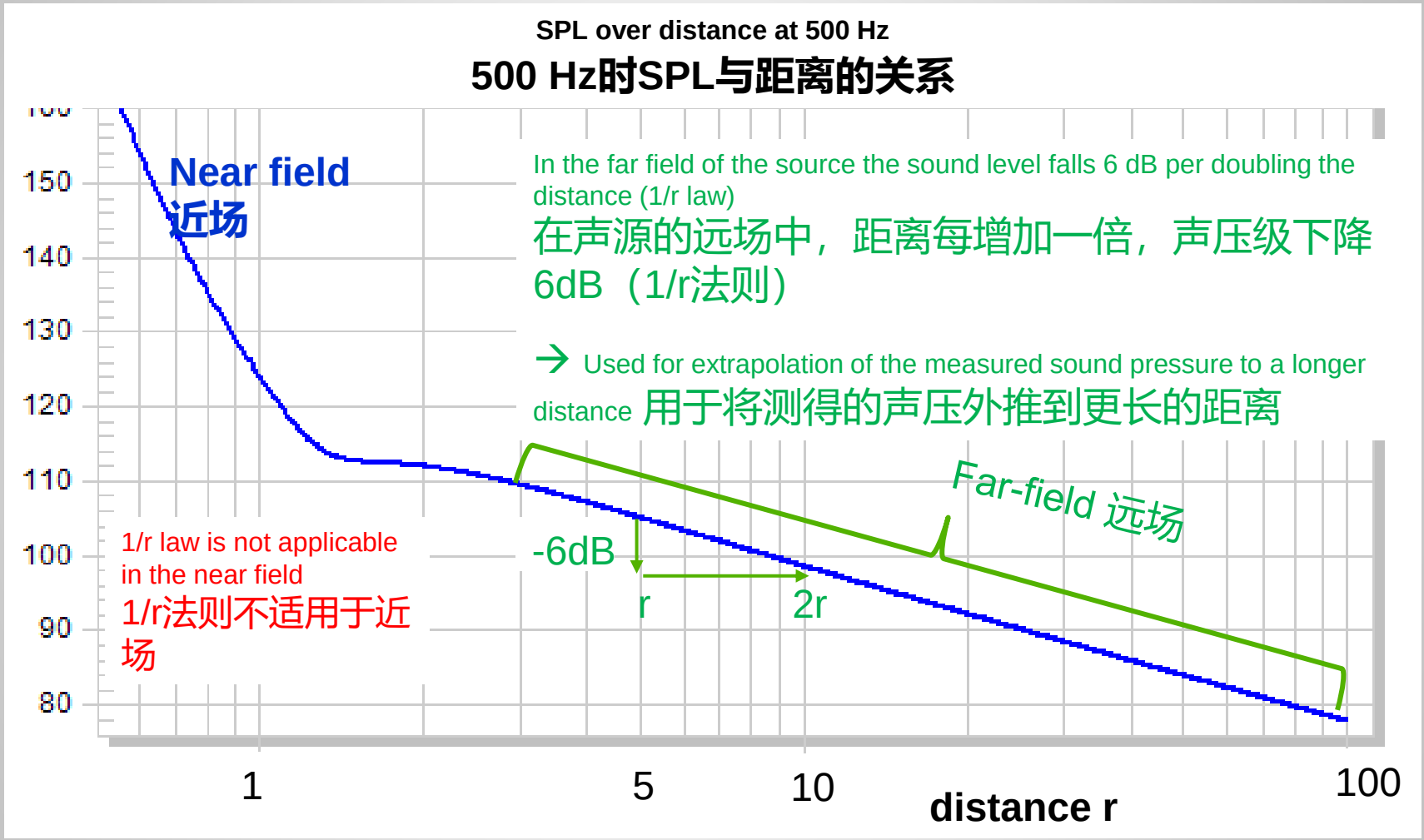
- Evaluation point re (usually on the reference axis)
  评估点$\mathbf{r}_e$（通常在参考轴上)
- evaluation distance re between reference point rref and evaluation point re
  参考点$\mathbf{r}_{ref}$和评估点$\mathbf{r}_e$之间的评估距离r_e

Is the evaluation point in the near or in the far field ?

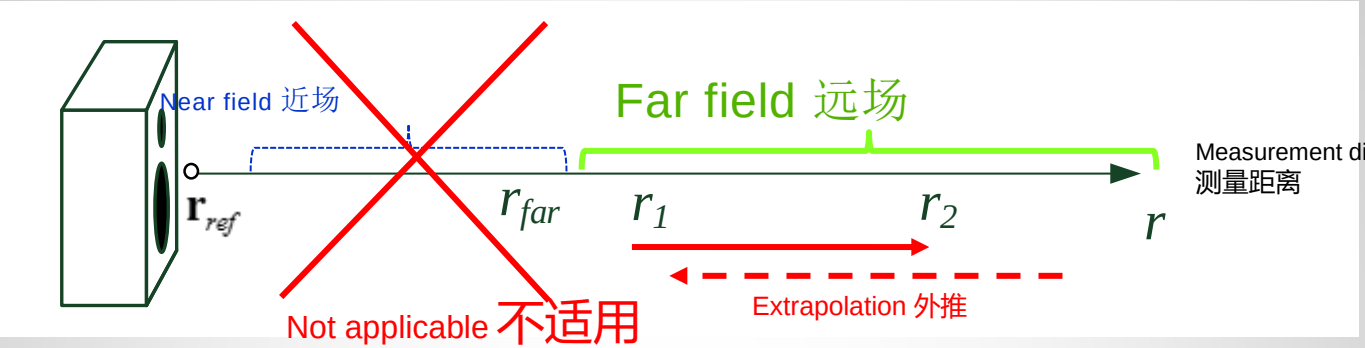
评估点是在近场还是远场?

Why are Far-Field Conditions Used ?

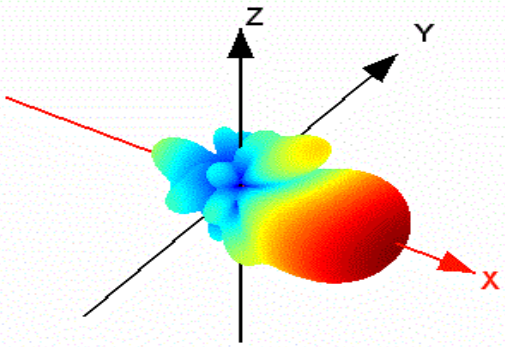
为什么要使用远场条件?



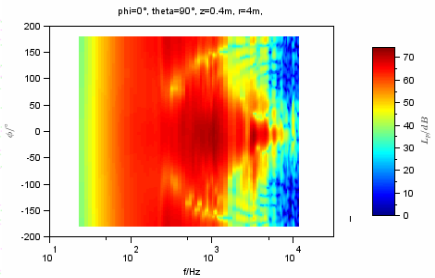
Extrapolation of Far Field data
远场数据的外推



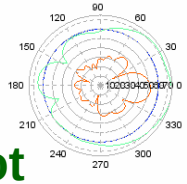
6.1 kHz at distance r=



Balloon Plot



Contour Plot



Polar Plot

$$\underline{H}(f, r_2, \theta, \phi) = \underline{H}(f, r_1, \theta, \phi) \frac{r_1}{r_2} e^{-jk(r_2 - r_1)}$$

Requirements:
要求

- free field condition (direct sound)
  自由场条件（直达声）
- *far field condition*
  远场条件
- same direction ($\phi_2 = \phi_1$, $\theta_2 = \theta_1$) 相同方向($\phi_2 = \phi_1$, $\theta_2 = \theta_1$)

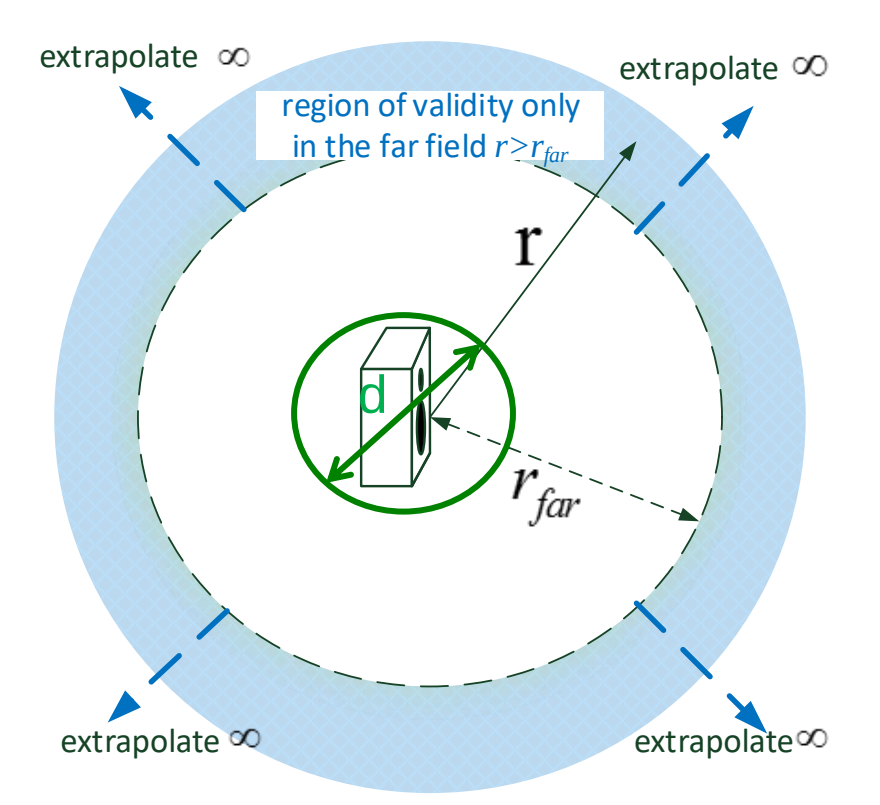
如何确保远场条件?

Requirements 要求:

- *Distance距离 r_{far} >> d*
  (critical for large geometrical dimension d, e.g. line array)
  （对于较大的几何尺寸d（例如线阵列）至关重要）

- *Distance距离 r_{far} >> λ*
  (critical at long wavelength λ, e.g. subwoofer)
  （对于长波长λ至关重要，例如超低音）

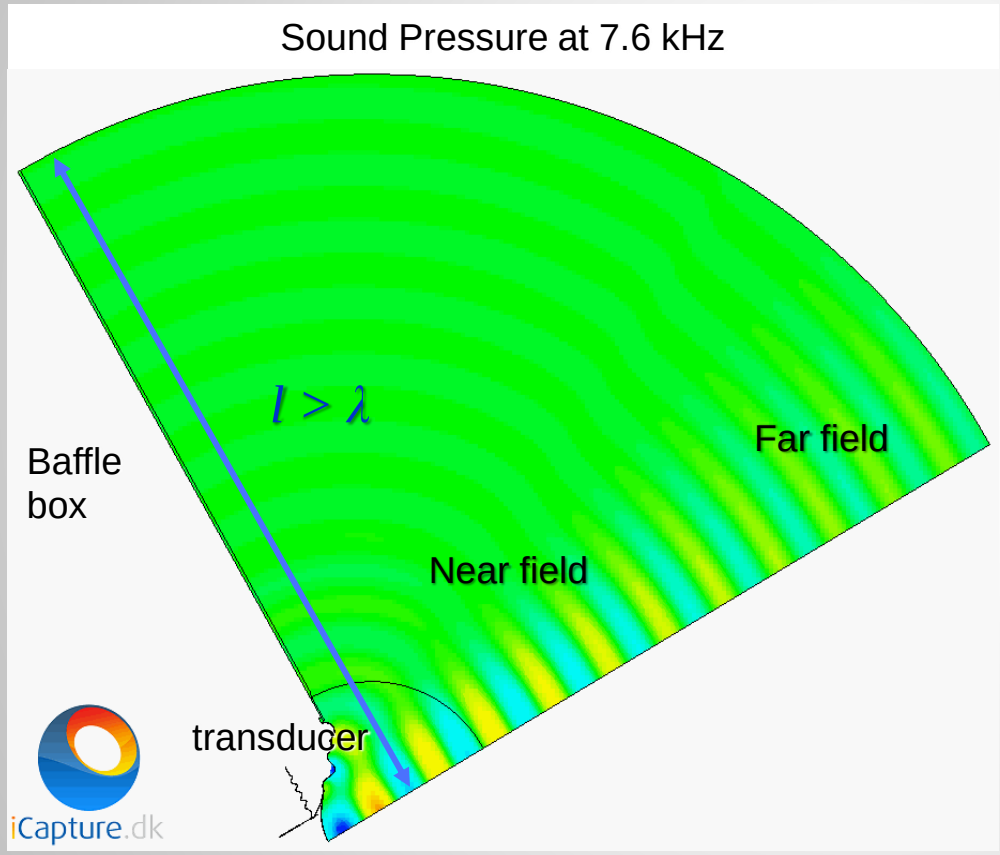
- *Ratio比率 r_{far} /d >> d/λ*
  (critical at short wavelength λ and large radiator dimension d, e.g. panel speaker)
  （在短波长λ和大辐射器尺寸d很关键，例如面板扬声器）



→ Large loudspeaker systems require large anechoic rooms ! (e.g. line arrays)
大型扬声器系统需要大型消声室！（例如线阵列）

Relevance of Near-Field Characteristics

近场特性的重要性



1. **Sound source has large dimensions** (e.g. line array)
声源尺寸较大（例如线阵列）

→ anechoic room is too small 消声室太小

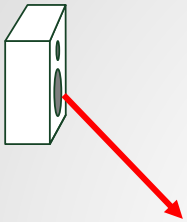
→ measurement point not in the far field 测量点不在远场

2. **The listener is close to the source** (e.g. personal audio equipment, car, multimedia, studio monitor, home equipment)
听音者靠近信号源（例如，个人音频设备、汽车、多媒体、演播室监视音箱、家用设备）

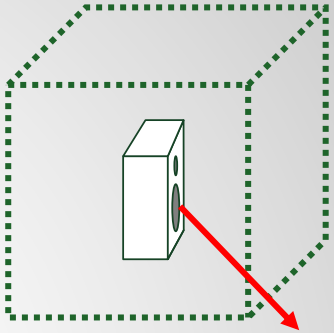
→ far field data are less meaningful 远场数据意义不大

声学测试环境

Free-field condition
自由场条件

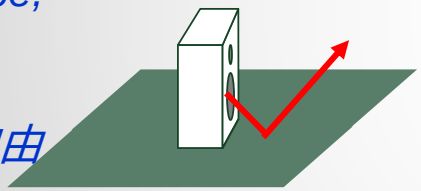


Simulated free-field condition
模拟自由场条件

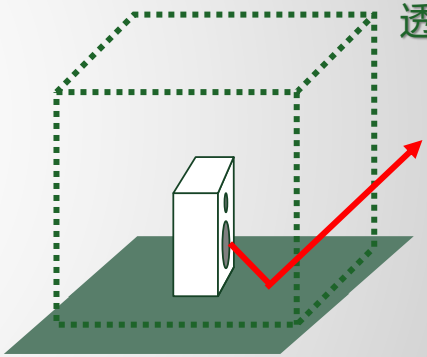


Transparent boundaries
透明边界

Half-space, free-field condition
半空间自由场条件

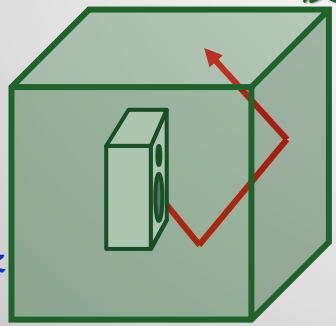


Simulated half-space, free-field condition
模拟半空间自由场条件

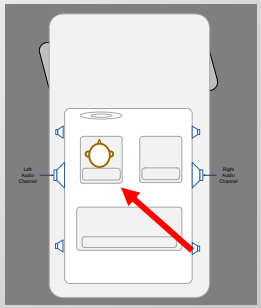


reflecting boundaries
反射的边界

Diffuse sound condition
扩散声场条件



Target application condition
目标应用条件



Free-field Condition according IEC 60268-21

基于IEC 60268-21的自由场条件

Problems 问题:

- **Anechoic rooms are not perfect!** Insufficient absorption generates wall reflections and standing waves at low frequencies.
  消音室并不完美! 吸收不足会在低频产生墙壁反射和驻波。
- **Finite size of the half space!** Edges generate sound reflections.
  半空间为有限尺寸! 边缘会产生声音反射。
- **Gating techniques are limited at low frequencies!** Insufficient distance to the boundaries (ground, walls, furniture) generates reflections which can not be separated by windowing of the impulse response.
  门限技术在低频受限! 到边界（地面、墙壁、家具）的距离不够时产生的反射无法通过脉冲响应加窗进行分离。

Consequences 后果:

Error in the measurement of the direct sound radiated from the DUT.
测量的从DUT辐射的直达声有误差。

IEC Requirement IEC要求:

State the limits of the valid frequency range where the measurement errors in the sound pressure exceed ±0.5 dB in amplitude and ±10° in phase.
指明有效频率范围的极限为声压的测量误差幅度超过±0.5 dB，相位超过±10°。

Practical Solution 实际解决方案:

Near field measurement with separation of outgoing and incoming waves.
近场测量，分离出射和入射波。

Other Test Conditions

其他测试条件

IEC 60268-21: Sound System Equipment, Part 21 Acoustical (output based) Measurements describes in detail:

IEC 60268-21：音响系统设备，第21部分声学（基于输出）的测量详细描述了：

- Climatic Test Condition

  气候测试条件

- Preconditioning of the Device

  设备预处理

- Mounting of the Device under test

  安装被测设备

- Additional information required (e.g. type description, design data)

  所需的其他信息（例如类型说明、设计数据）

Summary of the 1st section

第一节总结

- The value SPL_{max} is the basis for acoustical testing of modern audio systems
  SPL_{max}值是现代音频系统声学测试的基础
- The manufacturer shall rate the SPL_{max} according to IEC requirements.
  制造商应根据IEC要求评定SPL_{max}。
- The manufacturers assures that the device can generate the SPL_{max} at the rated condition without damage.
  制造商保证设备可以在额定条件下产生SPL_{max}而不会被损坏。
- The manufacture determines the physical and perceptual audio performance at the rated SPL_{max} according the particular application.
  制造商根据特定应用场景确定在额定SPL_{max}时的物理和感知音频性能。

Discussion
讨论

Open Questions

开放性问题

How to 如何

- perform standard measurements in a normal room? 在普通房间进行标准测量?
- generate SIMULATED free-field conditions according IEC 60268-21? 生成符合IEC 60268-21的模拟自由场条件?

Open Questions

开放性问题

How to 如何:

- perform standard measurements in a normal room? 在正常房间进行标准测量?
- generate SIMULATED free-field conditions according IEC 60268-21? 生成符合IEC 60268-21的模拟自由场条件?

The upcoming 2nd webinar will address:

即将举行的第二次网络研讨会将讨论:

- Practical limits of windowing direct sound in the impulse response
  对脉冲响应中的直达声进行加窗处理的实际限制
- Near field scanning and holographic processing
  近场扫描和全息处理
- Direct sound separation by modeling the wave propagation
  通过模拟波传播分离直达声

Next KLIPPEL LIVE in one week!
下一个星期的KLIPPEL LIVE!

1. 现代音频设备需要基于输出的测试 Modern audio equipment needs output based testing
2. **普通房间中进行标准声学测试 Standard acoustical tests performed in normal rooms**
3. 从3D输出测量中获取有意义的结论 Drawing meaningful conclusions from 3D output measurement
4. 评估点处的模拟标准条件 Simulated standard condition at an evaluation point
5. 最大SPL – 赋予该值意义 Maximum SPL – giving this value meaning
6. 选择具有高诊断意义得测量 Selecting measurements with high diagnostic value
7. 幅值压缩 – 输入更高但输出更低 Amplitude Compression – less output at higher amplitudes
8. 谐波失真测量 – 最佳实践 Harmonic Distortion Measurements – best practice
9. 互调失真 – 音乐比单音信号更多 Intermodulation Distortion – music is more than a single tone
10. 脉冲失真 – 异音、异常行为、缺陷 Impulsive distortion - rub&buzz, abnormal behavior, defects
11. 标准条件下音频产品的基准 Benchmarking of audio products under standard conditions
12. 信号失真的可听化 – 感知评估 Auralization of signal distortion – perceptual evaluation
13. 为信号失真设定有意义的公差 Setting meaningful tolerances for signal distortion
14. 评定产品的最大SPL值 Rating the maximum SPL value for a product
15. 带无线音频输入的智能音箱测试 Smart speaker testing with wireless audio input